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Shyu et al.

(54) **ELECTRONIC DEVICES WITH DISPLAYS**

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(51) **Int. Cl.**

H01L 27/32 (2006.01)

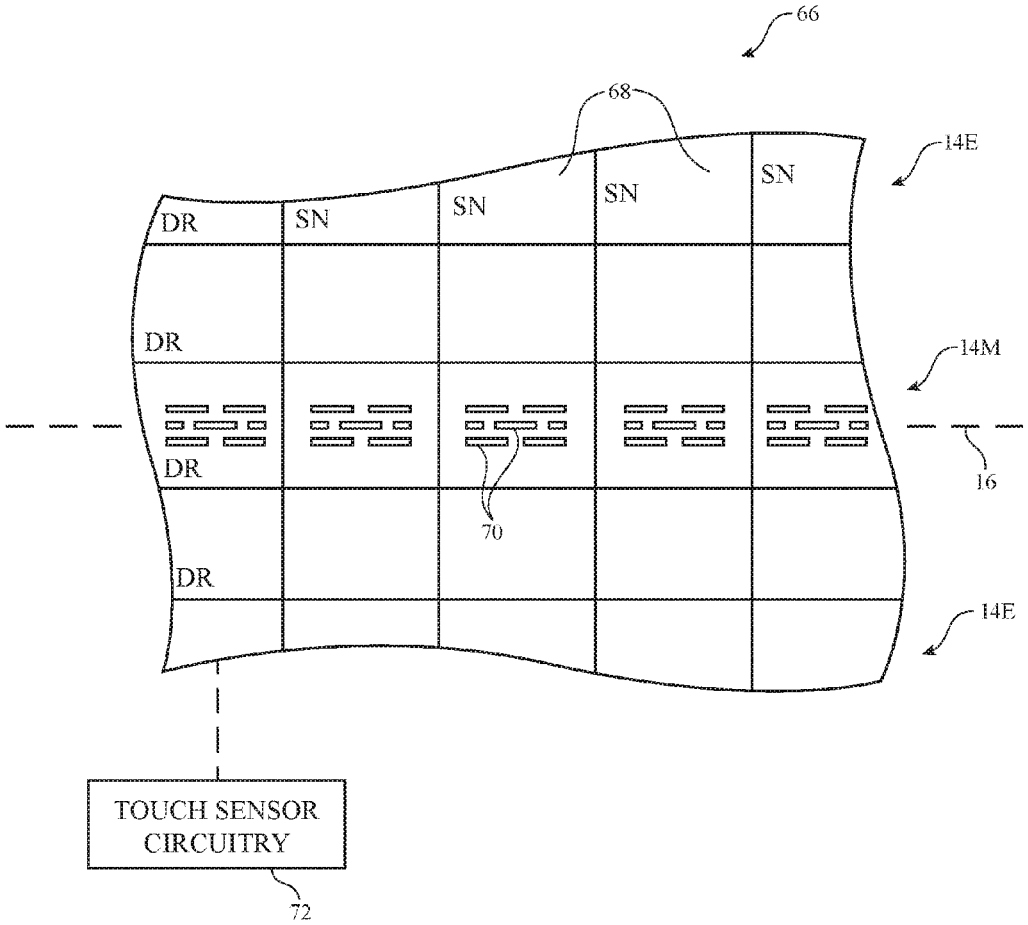
G06F 3/041 (2006.01)

(52) **U.S. Cl.**

CPC ***H01L 27/3248*** (2013.01); ***H01L 27/3211*** (2013.01); ***G06F 3/041*** (2013.01); *G06F 2203/04102* (2013.01); *G06F 3/044* (2013.01)

(57) **ABSTRACT**

An electronic device may have a flexible portion that allows the device to be folded. The device may have a flexible display. The flexible display may have edge portions that are joined along a flexible middle portion. The flexible middle portion may overlap a bend axis and may be bent about the bend axis. Flexibility enhancement regions may be formed in a backing layer, polarizer layer, organic-light-emitting display layer, and other display layers to enhance flexibility for the middle portion. The device may have a display with a flexible tail that is bent about a bend axis. Metal trace on the flexible display may include metal trace strips that serve as power lines. Flexibility enhancement regions such as slot-shaped openings or other openings may be formed in the metal trace strips to enhance flexibility.



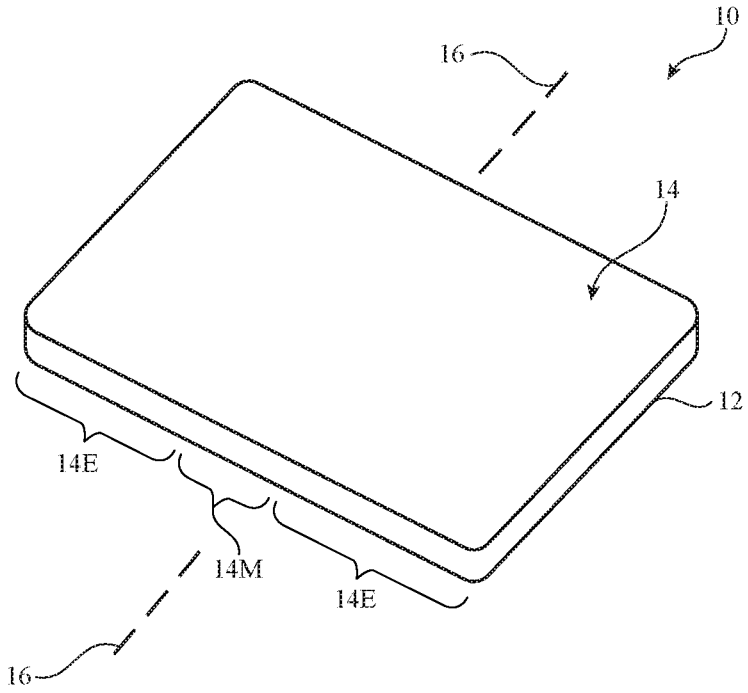


FIG. 1

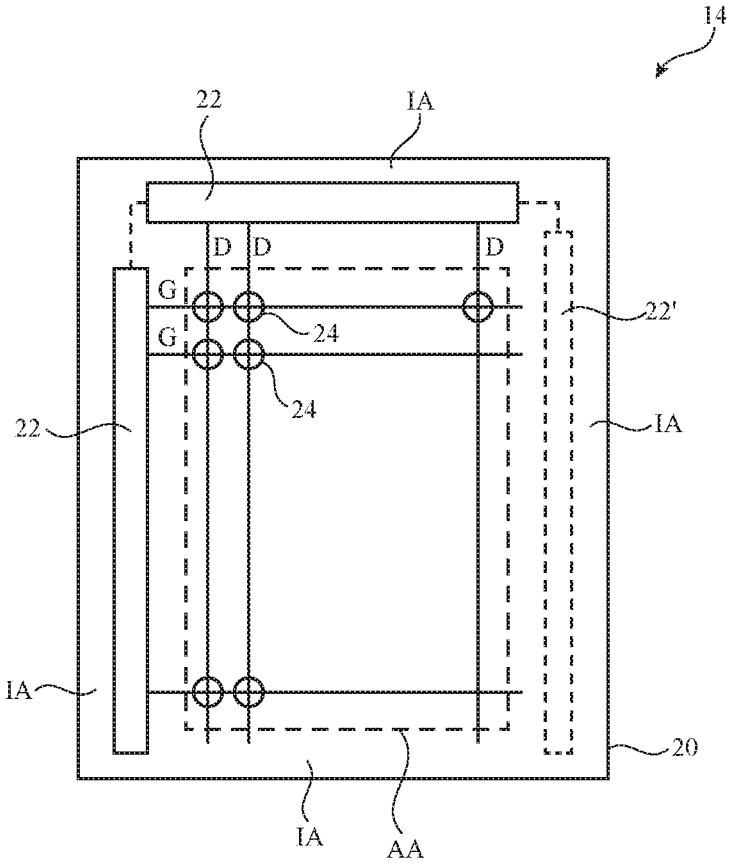


FIG. 2

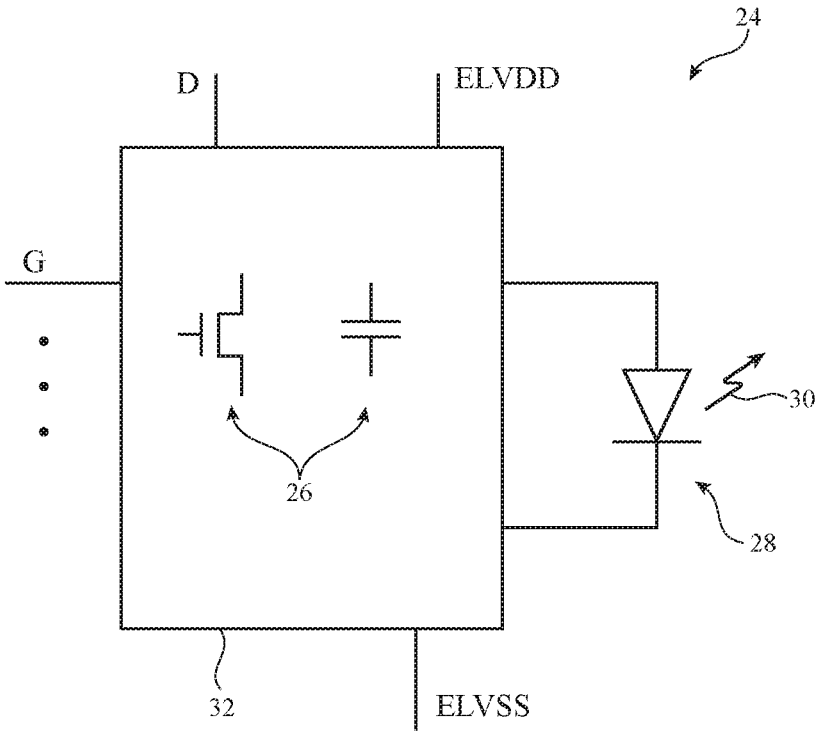


FIG. 3

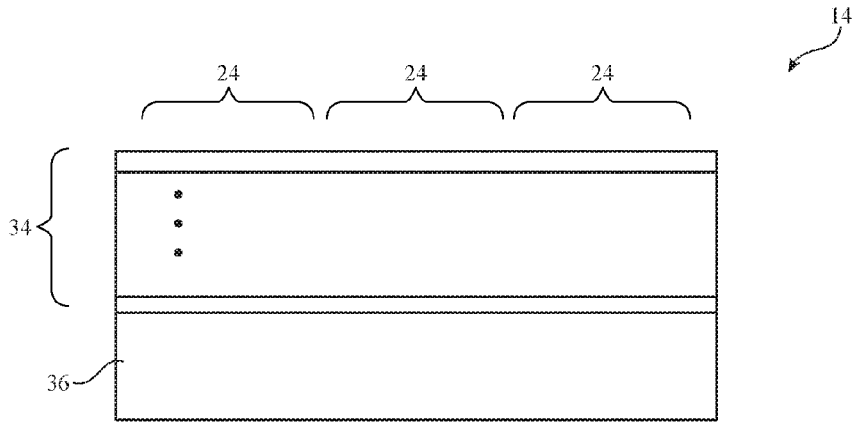


FIG. 4

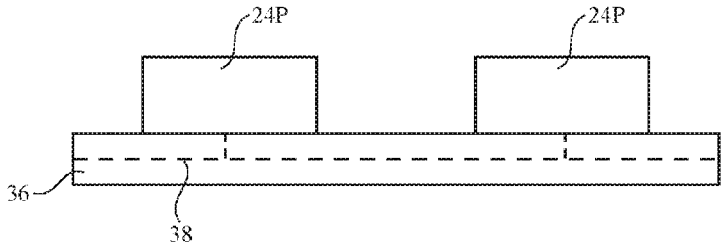


FIG. 5

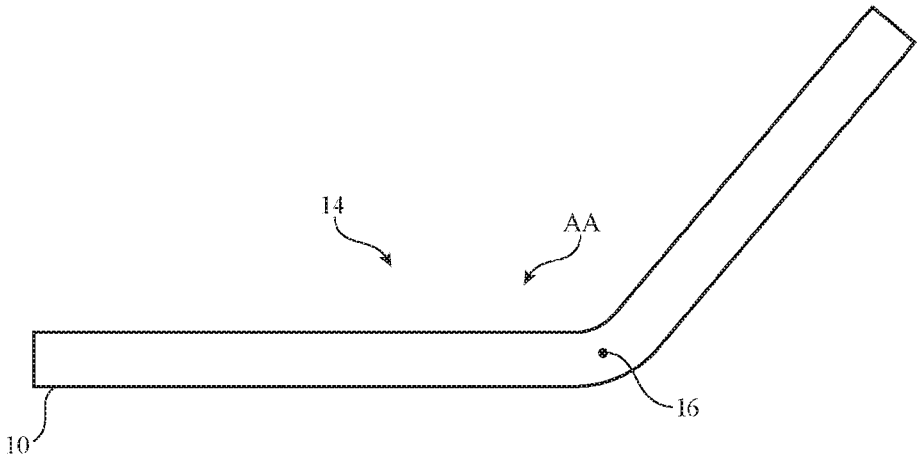


FIG. 6

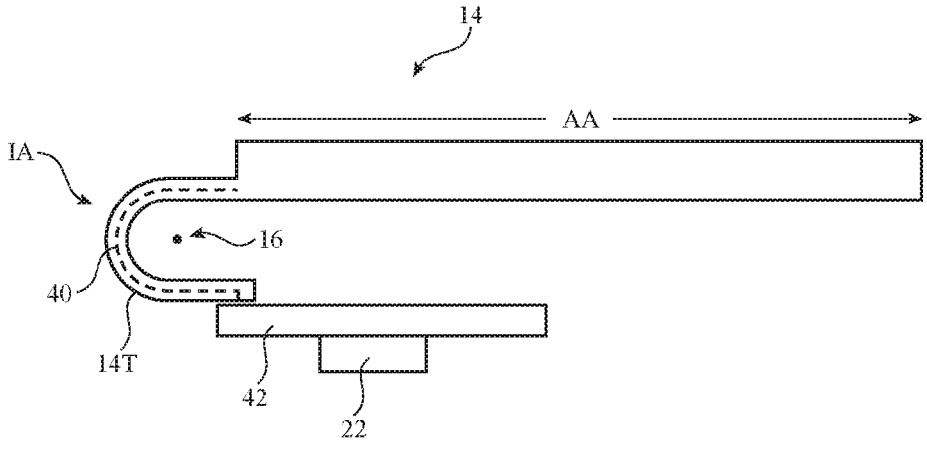


FIG. 7

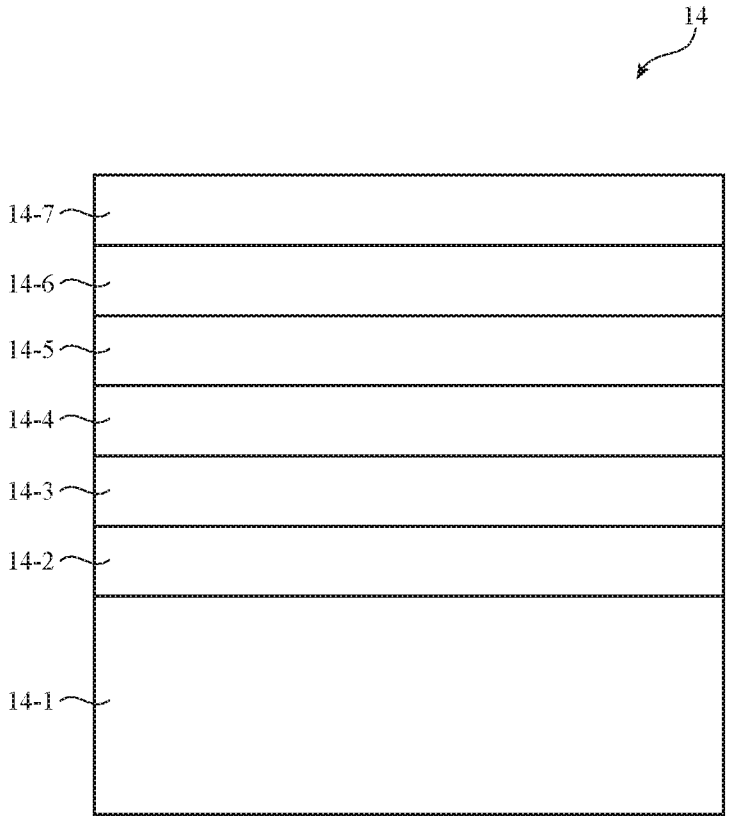


FIG. 8

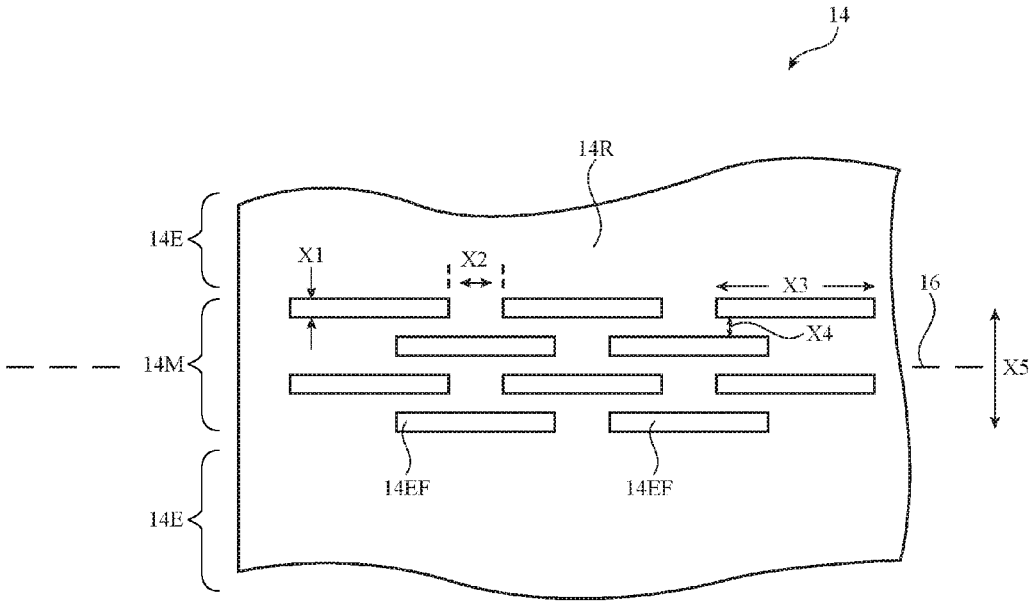


FIG. 9

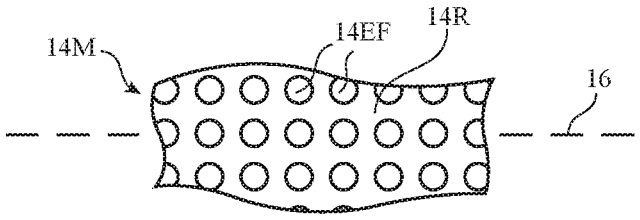


FIG. 10

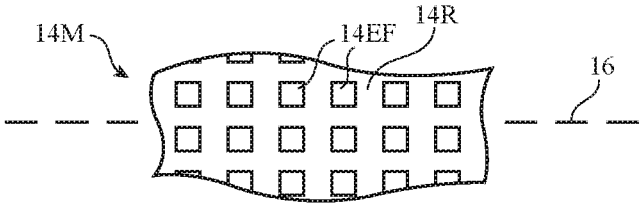


FIG. 11

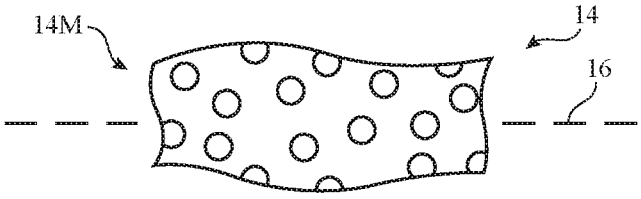


FIG. 12

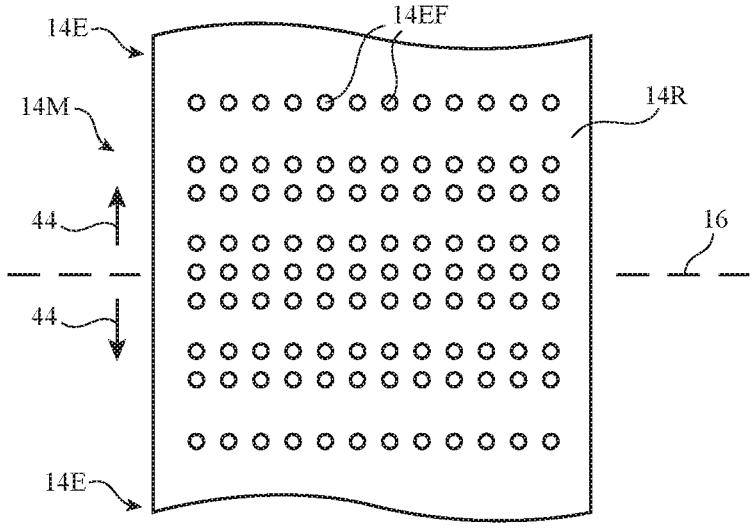


FIG. 13

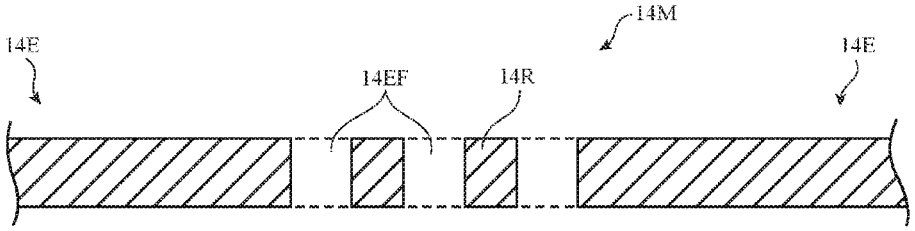


FIG. 14

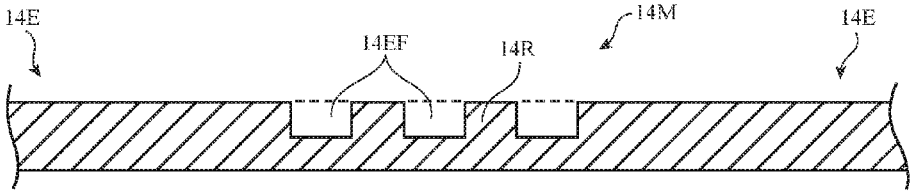


FIG. 15

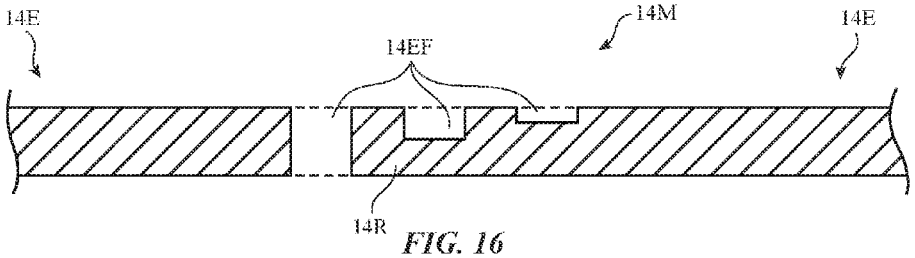


FIG. 16

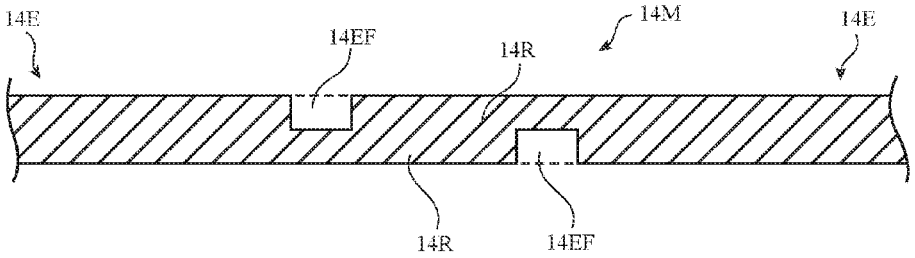


FIG. 17

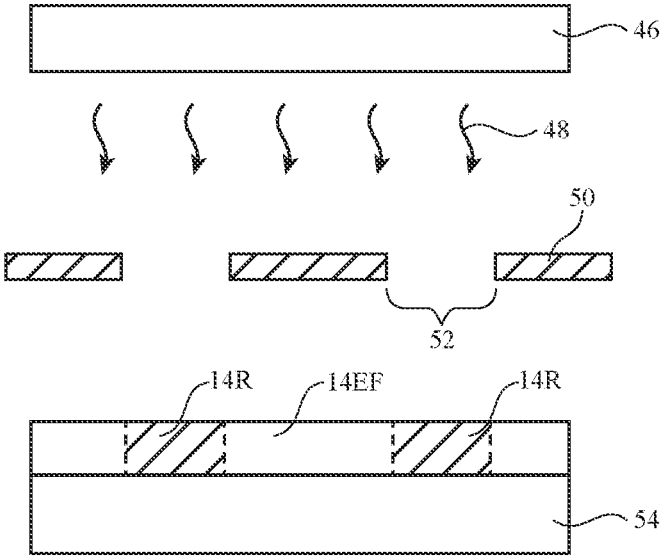


FIG. 18

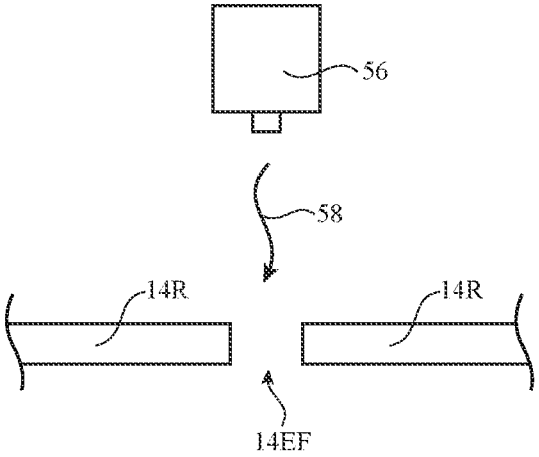


FIG. 19

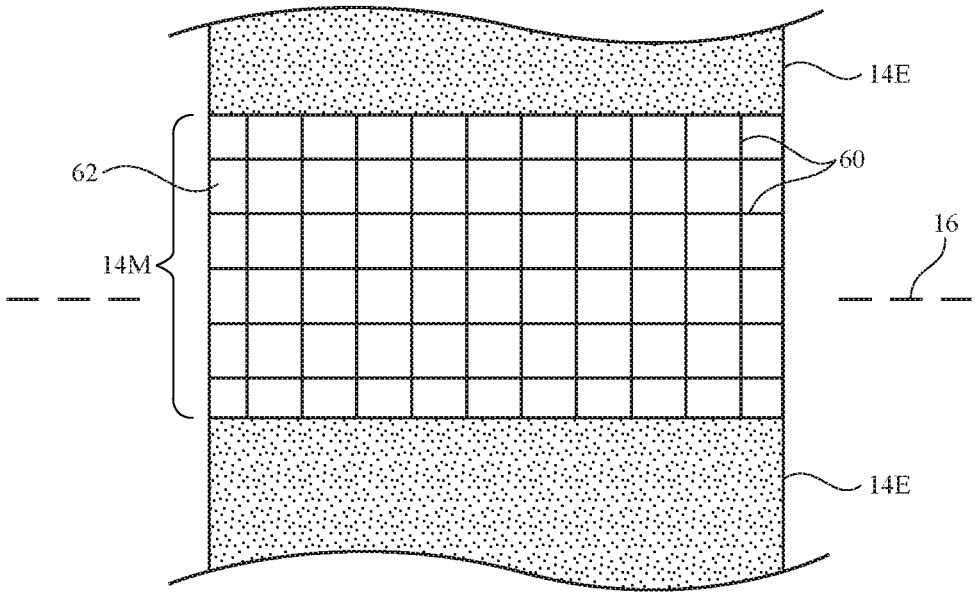


FIG. 20A

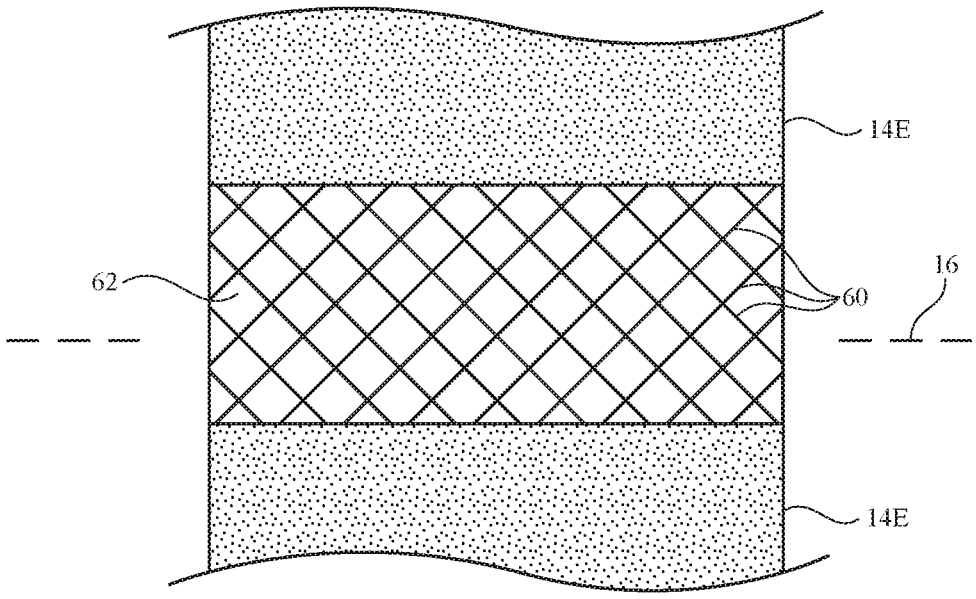


FIG. 20B

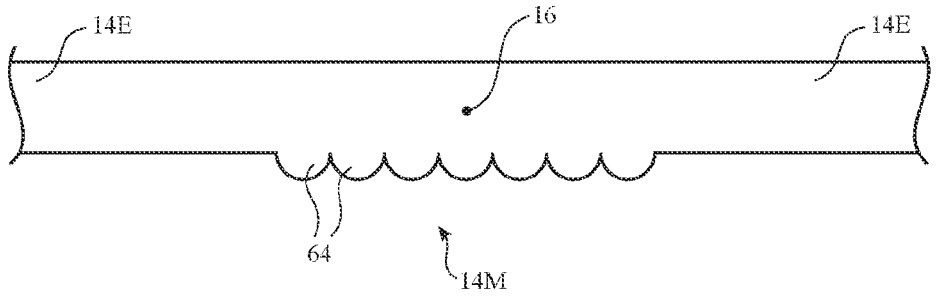


FIG. 21A

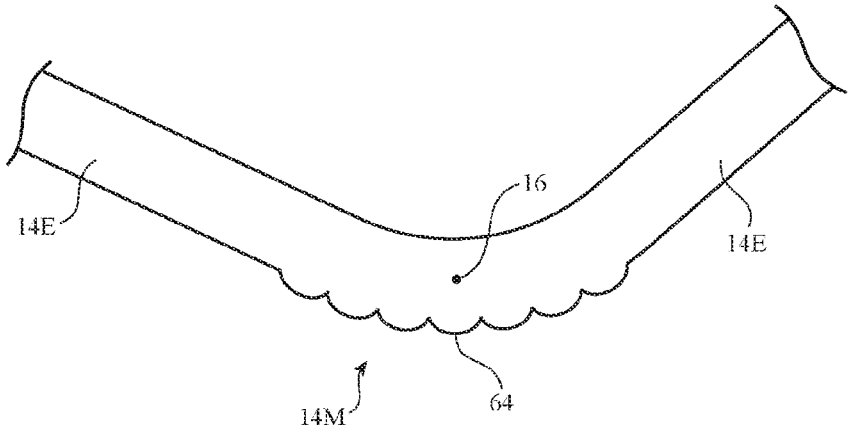


FIG. 21B

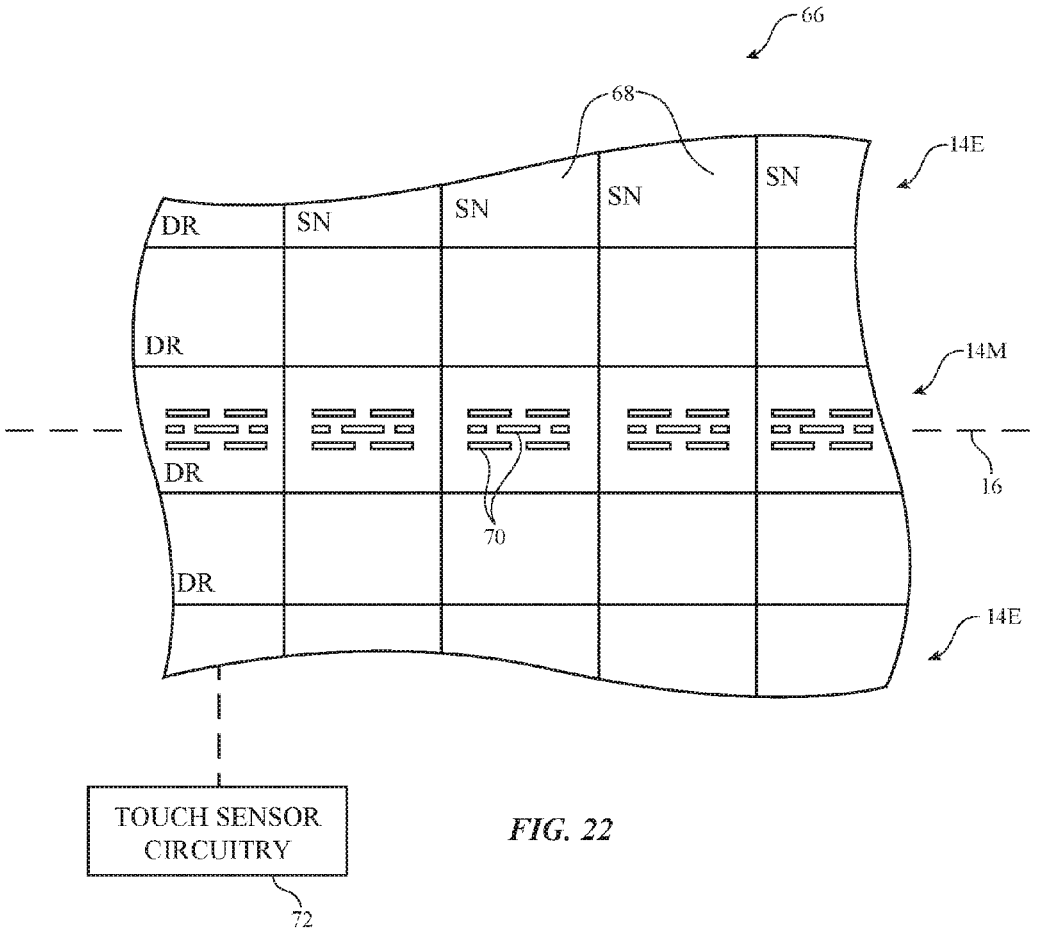

66
68
14E
SN
SN
SN
SN
DR
DR
DR
DR
14M
16
70
14E
TOUCH SENSOR CIRCUITRY
72

FIG. 22

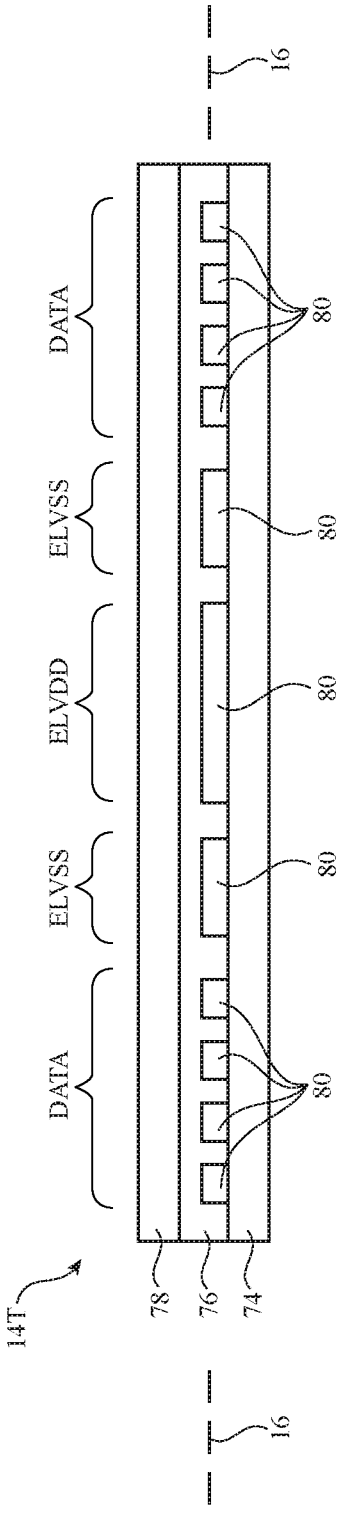


FIG. 23

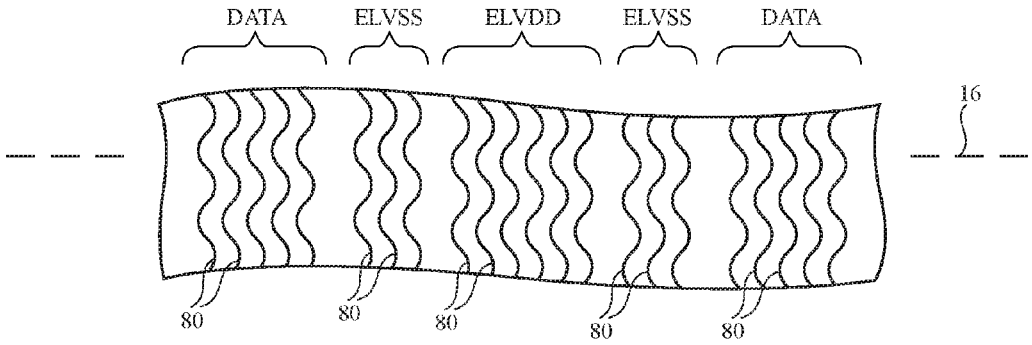


FIG. 24

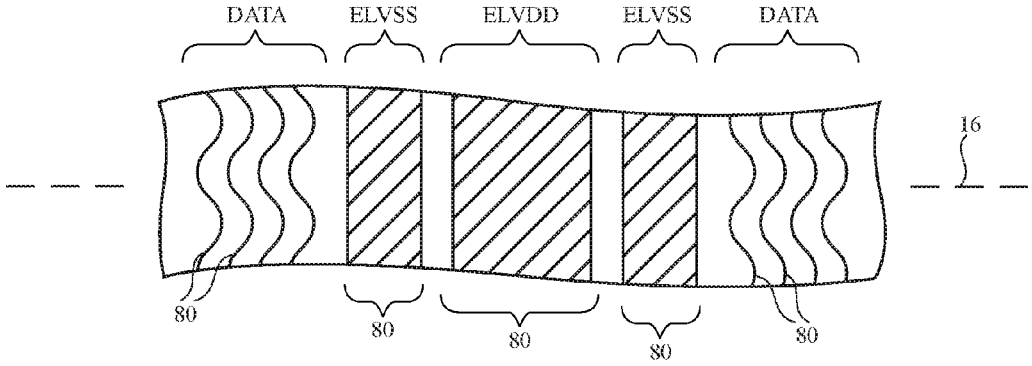


FIG. 25

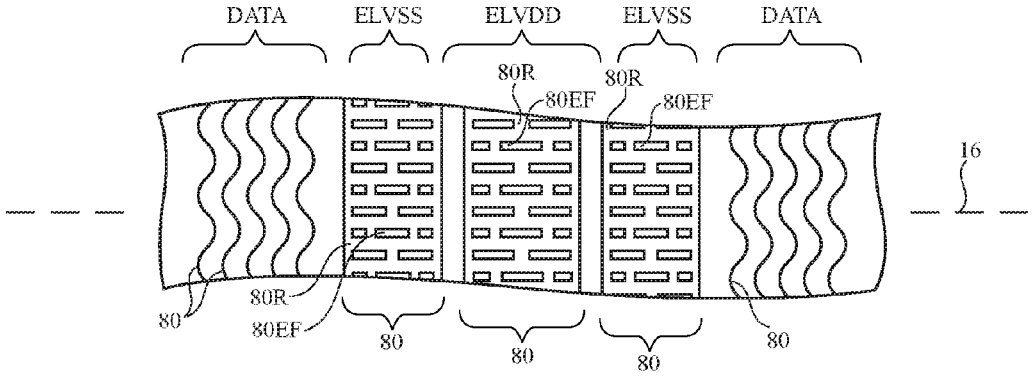


FIG. 26

ELECTRONIC DEVICES WITH DISPLAYS

[0001] This application claims priority to provisional patent application No. 62/320,333, filed Apr. 8, 2016, which is hereby incorporated by reference herein in its entirety.

BACKGROUND

[0002] This relates generally to electronic devices and, more particularly, to electronic devices with displays.

[0003] Electronic devices often include displays. For example, computers, cellular telephones, and other devices may use displays to present visual information to a user. It may be desirable to provide displays with flexible portions. This may allow portions of a display to be bent. Care must be taken, however, to ensure that displays are sufficiently robust to avoid damage when bent.

SUMMARY

[0004] An electronic device may have a flexible portion that allows the device to be folded. The device may have a flexible display and a housing in which the flexible display is mounted.

[0005] The housing and the flexible display may have edge portions that are joined along a flexible middle portion. The flexible middle portion may overlap a bend axis. The housing and flexible display may be bent about the bend axis. Flexibility enhancement regions may be formed in a backing layer, polarizer layer, a display layer such as an organic-light-emitting display layer or micro-light-emitting diode display layer, and may be formed in adhesive layers and other layers within the display to enhance bending about the bend axis.

[0006] The device may have a display with a flexible tail. The flexible tail may be bent about a bend axis when the display is mounted in a housing. Metal trace on the flexible display may include metal trace strips that serve as power lines. Flexibility enhancement regions such as slot-shaped openings or other openings may be formed in portions of the metal trace strips that overlap across the bend axis.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. **1** is a perspective view of an illustrative electronic device with a display in accordance with an embodiment.

[0008] FIG. **2** is a schematic diagram of an illustrative display in accordance with an embodiment.

[0009] FIG. **3** is a circuit diagram of an illustrative pixel in a display in accordance with an embodiment.

[0010] FIG. **4** is a cross-sectional side view of an illustrative organic light-emitting diode display in accordance with an embodiment.

[0011] FIG. **5** is a cross-sectional side view of an illustrative display with light-emitting diode pixels formed from individual crystalline semiconductor light-emitting diode dies in accordance with an embodiment.

[0012] FIG. **6** is a side view of an illustrative display with a bend in an active area of the display in accordance with an embodiment.

[0013] FIG. **7** is a side view of an illustrative display with a bend in an inactive area of the display in accordance with an embodiment.

[0014] FIG. **8** is a cross-sectional side view of an illustrative display in accordance with an embodiment.

[0015] FIGS. **9**, **10**, **11**, **12**, and **13** are top views of illustrative bend regions in a display having enhanced flexibility regions in accordance with an embodiment.

[0016] FIGS. **14**, **15**, **16**, and **17** are side views of a display layer showing illustrative configurations for enhanced flexibility regions in a display in accordance with an embodiment.

[0017] FIG. **18** is a diagram showing how patterned curing techniques may be used in forming a display with enhanced flexibility regions in accordance with an embodiment.

[0018] FIG. **19** is a diagram showing how material removal techniques such as laser drilling techniques may be used in forming a display with enhanced flexibility regions in accordance with an embodiment.

[0019] FIGS. **20**A and **20**B are top views of a display having a mesh structure such as a metal mesh in a bendable portion of the display in accordance with an embodiment.

[0020] FIGS. **21**A and **21**B are side views of a display having ribs that extend parallel to a bend axis in a bendable portion of the display in accordance with an embodiment.

[0021] FIG. **22** is a diagram showing how a touch sensor may be provided with enhanced flexibility regions in accordance with an embodiment.

[0022] FIG. **23** is a cross-sectional side view of an illustrative flexible display structure with metal traces for data and power signals in accordance with an embodiment.

[0023] FIGS. **24**, **25**, and **26** are top views of illustrative metal trace patterns for bendable display structures in accordance with an embodiment.

DETAILED DESCRIPTION

[0024] An electronic device such as electronic device **10** of FIG. **1** may have a display such as display **14**. Device **10** may be a laptop computer, a tablet computer, a cellular telephone, a wristwatch, or other electronic device (e.g., a portable device, handheld device, etc.).

[0025] Display **14** may be mounted in a housing such as housing **12**. Housing **12** may be formed of plastic, glass, ceramics, fiber composites, metal (e.g., stainless steel, aluminum, etc.), other suitable materials, or a combination of any two or more of these materials.

[0026] Display **14** may be a touch screen display that incorporates a layer of conductive capacitive touch sensor electrodes or other touch sensor components (e.g., resistive touch sensor components, acoustic touch sensor components, force-based touch sensor components, light-based touch sensor components, etc.) or may be a display that is not touch-sensitive. Capacitive touch screen electrodes may be formed from an array of indium tin oxide pads or other transparent conductive structures (as an example).

[0027] Display **14** may include an array of display pixels formed from liquid crystal display (LCD) components, an array of electrophoretic display pixels, an array of plasma display pixels, an array of organic light-emitting diode display pixels, an array of pixels formed from crystalline semiconductor light-emitting diode dies (sometimes referred to as micro-LEDs), an array of electrowetting display pixels, or display pixels based on other display technologies. Examples in which display **14** has been formed from organic light-emitting diode pixels or micro-LED pixels may sometimes be described herein as an example).

[0028] Display **14** may have one or more portions that bend. The bent portions may be flexed back and forth during use of device **10** (e.g., when device **10** is being opened and

closed like a book) or may be placed in a permanent bent configuration (e.g., when an inactive portion of display **14** is bent to accommodate mounting in a compact housing).

[0029] In the illustrative example of FIG. **1**, device **10** is bendable (foldable) along bend axis **16**. To accommodate bending about bend axis **16**, display **14** and housing **12** may have a flexible portion that overlaps bend axis **16**. For example, display **14** may have a flexible central portion **14**M and housing **12** may have an associated bendable central portion that runs along bend axis **16**. Bendable portion **14**M may be interposed between edge portions **14**E of display **14**. Edge portions **14**E may be rigid or flexible. For example, edge portions **14**E may be flexible display portions that are held rigid by rigid edge portions of housing **12**. Display **14** may be folded so that display portions **14**E face each other and/or so that portions **14**E face away from each other.

[0030] FIG. **2** is a diagram of an illustrative display. As shown in FIG. **2**, display **14** may have an array of pixels **24** formed on a substrate such as substrate **20**. Display driver circuitry **22** may include gate driver circuitry that is used to supply control signals G (sometimes referred to as horizontal control signals, emission control signals, scan signals, gate line signals, etc.) on horizontal lines (sometimes referred to as gate lines). There may be one or more gate lines associated with each row of pixels **24**. Gate driver circuitry may be located along one edge of display **14** (e.g., the left edge of display **14**) and/or two edges of display **14** (see, e.g., illustrative gate driver circuitry **22'** on the right edge of display **14** in the example of FIG. **2**). While control signals are being supplied to rows of pixels **24** using gate lines G, display driver circuitry **22** may be used to supply data signals D to pixels **24** using data lines that run along respective columns of pixels **24**. During operation, the active area AA of display **14**, which contains pixels **24**, displays images for a user. The inactive area IA of display **14** that runs along the borders of active area AA does not have any pixels **24** and therefore does not display images. Circuitry such as display driver circuitry **22**, routing lines, and other non-pixel circuitry may be located in inactive area IA.

[0031] An illustrative circuit of the type that may be used for pixels **24** is shown in FIG. **3**. As shown in FIG. **3**, pixel **24** may have pixel control circuitry **32** and light-emitting diode **28**. Control circuitry **32** may receive data signals D on vertical data lines and may receive control signals G on one or more horizontal control lines (gate lines). Control circuitry **32** may contain switching transistors, emission enable transistors, a drive transistor that controls current flow through light-emitting diode **28**, capacitors, and other circuitry (see, e.g., illustrative transistor and capacitor circuitry **26**). Power lines such as metal traces on display substrate **20** may carry positive power supply signal ELVDD and ground power supply signal ELVSS. Signals ELVDD and ELVSS may be used to power circuitry **32**. During operation, current is supplied to diode **28** that is proportional to the data loaded into circuitry **32**, causing diode **28** to emit a desired amount of light **30**. Pixels **24** may contain light-emitting diodes **28** of different colors (e.g., red, green, and blue) so that display **14** has the ability to display color images.

[0032] Light-emitting diode **28** and circuitry **32** may, if desired, be formed from thin-film circuitry. As shown in the illustrative cross-sectional side view of display **14** of FIG. **4**, for example, display **14** may have an array of pixels **24** that are formed from thin-film layers (thin-film circuitry) **34** on substrate **36**. In this type of thin-film display arrangement, light-emitting diode **28** may be an organic light-emitting diode and substrate **36** may be a flexible polymer substrate. Configurations in which light-emitting diodes **28** in display **14** are formed from discrete semiconductor dies may also be used (see, e.g., display **14** of FIG. **5** in which packaged or unpackaged micro-LEDs **24**P have been coupled to traces **38** on flexible polymer substrate **36**).

[0033] Displays such as illustrative displays **14** of FIGS. **4** and **5** may be bent about bend axis **16**, as illustrated in the display side views of FIGS. **6** and **7**. In the example of FIG. **6**, bend axis **16** overlaps active area AA of display **14**. When a user desires to fold display **14** for storage or to otherwise adjust display **14** in this type of configuration, active area AA of display **14** may be bent along bend axis **16**. In the example of FIG. **7**, inactive area IA of display **14** has been bent about bend axis **16**. As shown in FIG. **7**, display driver circuitry **22** (e.g., one or more display driver integrated circuit dies) may be mounted to printed circuit **42**. Printed circuit **42**, in turn, may be coupled to traces **40** in flexible tail portion **14**T in inactive area IA of display **14**. Inactive tail portion **14**T of display **14** may be a thin extending portion of one or more flexible polymer layers or other layers in active area AA of display **14** and may bend about bend axis **16** to accommodate the mounting of display **14** of FIG. **7** in a compact enclosure (as an example).

[0034] To accommodate either one-time bending or repeated folding and unfolding, the portions of display **14** that bend are preferably resistant to damage (e.g., cracking of brittle layers, plastic deformation, delamination, etc.). To help enhance durability, display **14** may be provided with enhanced flexibility regions. These regions may take the form of slots or other openings in the layers of display **14** and may help reduce potentially damaging stresses in one or more of the layers of display **14** during bending.

[0035] Display **14** may have a separate touch sensor layer, may have touch sensor structures that are formed from conductive traces on the same substrate as the circuitry that forms pixels **24**, or may not be touch sensitive. FIG. **8** is a cross-sectional side view of display **14** in an illustrative configuration in which display **14** has a touch sensor formed on a substrate layer that is attached to a flexible display layer using adhesive. Other configurations may be used for display **14** if desired (e.g., touch and/or protective layers may be omitted, additional layers may be added above or below the display, etc.). The configuration of FIG. **8** is presented as an example.

[0036] In the illustrative configuration of FIG. **8**, display **14** has a support layer **14-1** (sometimes referred to as substrate, backing layer, or backing film) such as layer **14-1**. Layer **14-1** may be, for example, a flexible polymer layer or a thin flexible metal layer (e.g., a nickel titanium layer). Layer **14-2** may be a layer of adhesive that attaches flexible display layer **14-3** to support layer **14-1**. Flexible display layer **14-3**, which may sometimes be referred to as a flexible display, may be, for example, an organic light-emitting diode display, a micro-LED display, or other flexible display. Adhesive layer **14-4** may be used to attach touch sensor (touch sensor layer) **14-5** to layer **14-3**. Touch sensor **14-5** may be formed from transparent conductive capacitive touch sensor electrodes (e.g., indium tin oxide electrodes) on a transparent polymer substrate (as an example). If desired, touch sensor electrodes may be integrated into layer **14-3**. Outer layer **14-7** of display **14** may include a polarizer (e.g., a circular polarizer formed from one or more flexible poly-

mer layers to reduce reflections from layer **14-3**), an inorganic scratch resistant layer (sometimes referred to as a hard coat), moisture barrier structures, coatings to promote smudge resistance, an antireflection layer, and/or other protective and functional layers. Adhesive layer **14-6** may be used to attach outer layer (polarizer layer) **14-7** to touch sensor **14-5**. Adhesive layers in display **14** may be formed from pressure sensitive adhesive, liquid adhesive (e.g., ultraviolet light curable liquid adhesive, etc.), or other suitable adhesive and may, if desired, be optically clear. Flexible substrate layers for support layer **14-1**, display layer **14-3**, and touch sensor **14-5**, may be formed from flexible polymers such as polyimide, polyethylene terephthalate (PET) or other polyesters, acrylic, or other polymers. If desired, metals may be incorporated into the layers of display **14** (e.g., as metal traces on substrates, a thin sheet of metal for forming support layer **14-1** or other layers, etc.). Semiconductor thin-films may be formed in display **14-3** (e.g., to form thin-film transistors). Other materials may also be used in forming one or more layers of display **14** (e.g., nanowires and other nanomaterials, fiber composite materials such as carbon fiber materials, ceramics, glass, etc.).

[0037] To prevent damage to display **14** during bending, one or more of layers **14-1**, **14-2**, **14-3**, **14-4**, **14-5**, **14-6**, and **14-7** and/or other display layers may be provided with flexibility enhancement regions. An illustrative configuration for display **14** in which one or more layers of display **14** have been provided with flexibility enhancement regions is shown in FIG. **9**. As shown in FIG. **9**, display **14** may have edge portions **14**E. Central flexible portion **14**M may extend between edge portions **14**E. Central flexible portion **14**M may run along and overlap bend axis **16**.

[0038] To enhance the flexibility of display **14** and thereby help reduce bend-induced stresses, solid portion **14**R of one or more layers in region **14**M may be provided with enhanced flexibility regions **14**EF. Regions **14**EF may be openings (e.g., through-holes), may be grooves or other recesses, or may have other configurations. In the example of FIG. **9**, regions **14**EF have elongated slot shapes. Regions **14**EF may have dimensions such as widths X**1** and lengths X**3**, may be separated along their lengths by gaps X**2** and along their widths by gaps X**4**. Region **14**M may have a width X**5**. With one illustrative configuration, X**1** may be 100 microns, more than 10 microns, or less than 500 microns, X**2** may be 5 mm, more than 1 mm, or less than 2 cm, X**2** may be 500 microns, more than 100 microns, less than 2 mm, X**4** may be 500 microns, more than 100 microns, less than 2 mm, etc., and X**5** may be 100 microns to 1 cm, more than 1 mm, or less than 5 mm, and/or these dimensions may have any other suitable values. Slot-shaped elongated openings or other elongated flexibility enhancement regions **14**EF such as regions **14**EF of FIG. **9** may be staggered (as shown in FIG. **9**) to help preserve the structural integrity of the display layer(s) in which regions **14**EF have been formed.

[0039] Regions **14**EF may be circular (as shown in FIG. **10**), may be rectangular (as shown in FIG. **11**), or may have any other suitable shape. Regions **14**EF may be distributed in a regular periodic pattern (e.g., an array having rows and columns) or may be distributed pseudorandomly (see, e.g., the illustrative aperiodic distribution of FIG. **12**). If desired, regions **14**EF may be distributed with a density that varies across region **14**M (see, e.g., FIG. **13** in which regions **14**EF decrease in density with increasing distance **44** from bend axis **16**).

[0040] Regions **14**EF may pass entirely through a display layer (see, e.g., through-hole openings **14**EF of FIG. **14**), may pass partly through a display layer (see, e.g., recesses **14**EF of FIG. **15**), may include through-hole openings and/or recesses of one or more different depths (see, e.g., illustrative regions **14**EF of FIG. **15**), and/or may be formed on one or more sides of a display layer (see, e.g., FIG. **17**).

[0041] As shown in FIGS. **14**, **15**, **16**, and **17**, regions **14**EF may be filled with a flexible material. The flexible material may be a liquid, a gel, foam, a solid polymer (e.g., a soft elastomeric polymer), a liquid polymeric material, or other flexible material. The flexible material in regions **14**EF may be formed from a material that is more flexible and/or different than the material of region **12**R. If desired, regions **14**EF may be filled with air or other gaseous material.

[0042] FIG. **18** shows how light-source **46** (e.g., an ultraviolet light source) may supply ultraviolet light **48** when processing a display layer. Mask **50** may have openings **52** that allow light **48** to selectively cure a liquid polymer precursor material to form stiffer regions **14**R in the display layer. Uncured portions of the liquid polymer material may remain uncured or partly cured and may remain in liquid form or may otherwise be more flexible than cured stiffer regions **14**R. This allows the uncured portions to serve as enhanced flexibility regions. If desired, etching equipment, cutting equipment, machining equipment, laser-processing equipment, or other material removal tools may be used in removing portions of a display layer to form regions **14**EF (see, e.g., FIG. **19** in which laser **56** produces laser beam **58** to laser drill recesses or openings in layer **14**R that serve as enhanced flexibility regions **14**EF). After removing material from regions of a display layer, the regions may contain air or may optionally be filled with a material such as liquid, gel, solid polymer (e.g., polymer that is more flexible than the non-removed polymer), or other material that allows the regions to bend.

[0043] When filling regions of a layer in display with material to form enhanced flexibility regions **14**EF (or when leaving liquid polymer regions uncured), the added material (or uncured material) may be opaque or transparent. Transparent filler materials may be used in scenarios in which image light from pixels **24** is passing through the transparent filler. In situations such as these, the transparent filler material may be index matched to the unremoved portions of the display layer (e.g., the index of refraction of the material that is added to regions **14**EF may vary by less than 0.1 or by less than 0.05 or other suitable amount from the index of refraction of remaining material **14**R). Index matching may help reduce light scattering.

[0044] As shown in FIG. **20**A, portion **14**M of display **14** may have one or more layers with a mesh structure such as grid **60**. Grid **60** may be formed from metal wires or a sheet of metal with openings (e.g., an array of rectangular openings or openings of other shapes). The openings in mesh **60** may be filled with air or filler material **62** (e.g., elastomeric material, etc.). Grid **60** may be formed from wires, fine lines of a metal thin-film, or other material. The lines may be sufficiently narrow to be invisible to a user of device **10** and/or grid **60** may be formed in a layer of display **14** that is not visible to the user (see, e.g., backing film **14-1** of FIG. **8**). Backing film **14-1** may also be formed from a metal sheet

(e.g., a thin sheet of nickel titanium or other flexible metal). To enhance the flexibility of a metal backing film, the metal sheet may be provided with flexibility enhancement regions **14**F (e.g., staggered slot-shaped openings, an array of rectangular or circular openings, openings of other shapes, etc.). A metal sheet with grooves or other recesses that pass only partway through the metal sheet may also be used in forming a backing film **14-1**. In the example of FIG. **20**A, the lines of mesh **60** run parallel and perpendicular to bend axis **16**. FIG. **20**B shows how the lines of mesh **60** may be oriented so that they run at 45° relative to bend axis **16**. Other mesh orientations and layouts may be used if desired. Fiber-based materials may also be used in forming layers in display **14**. For example, backing layer **14-1** may be formed from a flexible fiberglass layer or other fiber-impregnated material (e.g., an elastomeric material with glass or carbon fibers, etc.).

[0045] As shown in the cross-sectional side view of display **14** of FIG. **21**A, one or more of the layers of display **14** (e.g., backing layer **14-1**) may be provided with protrusions that help provide support while retaining flexibility. In the example of FIG. **21**A, a layer of display **14** has series of parallel ribs **64** in region **14**M (i.e., elongated raised portions that run parallel to bend axis **16**). FIG. **21**B shows how the depressed regions between adjacent pairs of ribs may help enhance the flexibility by facilitating bending around bend axis **16**.

[0046] Display **14** may have a touch sensor. The touch sensor may be a stand-alone capacitive touch sensor layer such as layer **14-5** of FIG. **8** or may be formed from capacitive touch sensor electrodes that have been integrated into display **14-3**.

[0047] A top view of an illustrative touch sensor is shown in FIG. **22**. As shown in FIG. **22**, touch sensor **66** may have drive lines DR and perpendicular sense lines SN. Touch sensor circuitry **72** may be coupled to drive lines DR and to sense lines SN. Touch sensor circuitry **72** may supply drive signals to drive lines DR and may monitor sense lines SN for signals that have been coupled into a given sense line SN from one of drive lines DR due to the presence of a user's finger or other overlapping external component (e.g., a stylus) at the intersection between that drive line and sense line.

[0048] Capacitive touch sensors may use single-sided or double-sided electrode patterns. Capacitive touch sensor electrodes may be formed from transparent conductive material such as indium tin oxide. As an example, each drive line DR in sensor **66** of FIG. **22** may be formed from a horizontal strip of indium tin oxide on the upper surface of a clear plastic substrate and each sense line SN in sensor **66** may be formed from a vertical strip of indium tin oxide on the lower surface of the clear plastic substrate. Enhanced flexibility regions **70** may be formed in the substrate layer and/or electrode layer(s) of touch sensor **66**. Regions **70** may, for example, run along and overlap bend axis **16**, as shown in FIG. **22**. Regions **70** may be formed from staggered slots or other elongated openings in the indium tin oxide layers and/or the clear plastic substrate, from grooves or other recesses in these layers, etc. The area consumed by regions **70** may be relatively small and there may be spaces between regions **70**, so the presence of the enhanced flexibility regions **70** may only slightly raise the resistance of the touch sensor electrodes, thereby ensuring that touch sensor **66** may operate satisfactorily.

[0049] FIG. **23** is a cross-sectional side view of a portion of display **14** (e.g., a portion in an inactive tail region such as region **14**T of FIG. **7**). As shown in FIG. **23**, a display portion such as portion **14**T may have a substrate such as substrate **74** (e.g., a layer of polyimide or other flexible polymer layer). Metal traces **80** may be patterned onto layer **74** and used to form data line signal paths (DATA) and power paths (e.g., positive power supply path ELVDD and a pair of flanking ground power supply paths ELVSS in the FIG. **23** example). Planarization layer **76** may be formed from a polymer layer that is deposited as a liquid and that remains flexible when cured to a solid state. Optional neutral stress plane adjustment layer **78** may be formed on top of layer **76** and may be used to ensure that the neutral stress plane of tail **14**T is aligned with metal traces **80** when tail **14**T is bent about bend axis **16** as shown in FIG. **7**, thereby minimizing bending-induced stress in traces **80**. By minimizing stress in traces **80**, faults due to trace cracks may be avoided.

[0050] Stress that has the potential to lead to undesired cracks in metal traces **80** may also be minimized by selection of appropriate shapes for traces **80** in the portion of traces **80** that runs across bend axis **16**. In the example of FIG. **24**, traces **80** for DATA, ELVSS, and ELVDD have serpentine shapes (i.e., the traces are serpentine metal lines). This may help minimize trace stress, because serpentine paths can stretch slightly when bent about axis **16**. In the example of FIG. **25**, data lines DATA are formed from serpentine traces **80** and power lines (e.g., ELVSS and ELVDD) have been formed from solid metal trace strips to help reduce power line resistance. FIG. **26** shows how solid metal trace strips for power traces such as ELVSS and ELVDD (i.e., metal trace strips **80**R) may be provided with flexibility enhancement regions **80**EF. Flexibility enhancement regions **80**EF may be, for example, staggered slots or other elongated openings that pass through traces **80**R or may be openings of other suitable shapes. Regions **80**EF do not completely span the widths of traces **80**R, so traces **80**R remain conductive. If desired, patterned thin-film metal traces such as the traces of FIGS. **24**, **25**, and/or **26** or other serpentine traces and/or traces with openings that serve as flexibility enhancement regions may be formed in multiple layers of a display and may be shorted together using metal vias.

[0051] The foregoing is merely illustrative and various modifications can be made by those skilled in the art without departing from the scope and spirit of the described embodiments. The foregoing embodiments may be implemented individually or in any combination.

What is claimed is:

1. An electronic device, comprising:

a housing; and

a flexible display in the housing having a bending region that bends about a bend axis, wherein the flexible display has a plurality of layers and wherein at least one of the display layers includes a metal sheet with openings that serve as flexibility enhancement regions.

2. The electronic device defined in claim **1** wherein the metal sheet forms a backing layer for the flexible display and wherein the flexible display further comprises a flexible display layer having an array of pixels.

3. The electronic device defined in claim **2** wherein the flexible display layer with the array of pixels is attached to the backing layer with a layer of adhesive.

4. The electronic device defined in claim 3 wherein the flexible display further comprises a touch sensor layer that is attached to the flexible display layer with a layer of adhesive.

5. The electronic device defined in claim 4 wherein the metal sheet comprises nickel titanium.

6. The electronic device defined in claim 4 wherein the openings comprise slots that run parallel to the bend axis.

7. The electronic device defined in claim 4 wherein the flexible display layer comprises a flexible substrate and thin-film circuitry on the flexible substrate that forms organic-light-emitting diodes and thin-film transistors for the pixels.

8. The electronic device defined in claim 4 wherein the flexible display layer comprises a flexible substrate and wherein the pixels each include a respective crystalline semiconductor light-emitting diode die coupled to the flexible substrate.

9. A flexible display, comprising:

an active area having an array of pixels that emit light; and

an inactive tail portion that extends from the active area and that bends about a bend axis, wherein the inactive tail portion includes serpentine data lines and metal trace strips that serve as power supply lines, wherein each of the metal trace strips has a respective portion that overlaps the bend axis and wherein each of the portions of the metal trace strips that overlaps the bend axis has a plurality of openings that serve as flexibility enhancement regions for that metal trace strip.

10. The flexible display defined in claim 9 wherein the pixels include light-emitting diodes.

11. The flexible display defined in claim 10 wherein the light-emitting diodes comprise organic light-emitting diodes.

12. The flexible display defined in claim 10 wherein the light-emitting diodes comprise crystalline semiconductor light-emitting diode dies.

13. An electronic device that folds about a bend axis, comprising:

a housing having edge portions and having a middle portion that is coupled between the edge portions; and

a flexible display having edge portions in the edge portions of the housing and having a flexible middle portion that overlaps the middle portion of the housing, wherein the flexible display has a backing layer, a flexible organic light-emitting diode display layer, and a polarizer layer, and wherein at least the backing layer has a plurality of elongated flexibility enhancement regions in the flexible middle portion and wherein each of the elongated flexibility enhancement regions extends along the bend axis to enhance flexibility of the flexible middle portion of the flexible display as the flexible display bends about the bend axis.

14. The electronic device defined in claim 13 wherein the elongated flexibility enhancement regions comprise staggered slots.

15. The electronic device defined in claim 14 wherein the slots extend through the backing layer.

16. The electronic device defined in claim 14 wherein the slots extend only partway through the backing layer.

17. The electronic device defined in claim 16 wherein the slots include slots of different depths.

18. The electronic device defined in claim 14 further comprising elastomeric material in the slots.

19. The electronic device defined in claim 14 wherein the slots are laser-formed openings and wherein the backing layer comprises a polymer layer through which the laser-formed openings pass.

20. The electronic device defined in claim 13 wherein the polarizer has an index of refraction and wherein the polarizer has recesses that are filled with material having an index of refraction that is matched to the index of refraction of the polarizer.

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